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MODELING AND FINITE ELEMENT ANALYSIS OF DELAMINATED COMPOSITE BEAMS

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Abstract - *An aircraft wing is mainly subjected to lift, fuel, engine, and landing gear, inertial, structural, non-structural and other aerodynamic loads. The main load-bearing members in the wing are called spars. The spars are the principle structural members. Spars are strong beams which run span wise in the wing and carry the force and moments due to the span wise lift distribution.*

Wings of aircraft are attached at the root to the fuselage. A wing has two beams. One beam is usually located near the front of the wing, and the other about two-thirds of the distance toward the wing's trailing edge beams run parallel to the lateral axis of the aircraft, from the fuselage toward the tip of the wing, and are usually attached to the fuselage by wing fittings, plain beams, or a truss. Wings of aircraft are subject to be cantilever beams with different cross sections based on requirement of aircraft.

In this paper the aircraft spar wing beam with different delamination positions (X-0, X-0.3, X-0.5 & X-0.7) designed in CREO parametric software and analyzed in ANSYS software. Static structural, Fatigue and Modal analysis are performed on Rectangular cantilever composite beam with single-edge deformation. Static structural, Fatigue and Modal analysis are performed to analyze the stress, safety factor and natural frequency of different materials at different delamination length ratios. Presently used materials are conventional materials (Aluminium alloy) but in this project we replaced with composite materials (Carbon fibre reinforced polymer, S-2 glass fibre reinforced polymer & Kevlar fibre reinforced polymer). It is obtained that composite material has given better performance compared to conventional material (Aluminium alloy).

Key Words: **Delaminated composite beam, Fibre-reinforced epoxy polymers, Aircraft wing, CREO parametric software, ANSYS, Safety factor, Life, Fatigue analysis, etc.**

1. INTRODUCTION TO BEAMS

1.1 BEAM

A beam (Fig. 1) is a structural element that is capable of withstanding load primarily by resisting against bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment. Beams are characterized by their profile (shape of cross-section), their length, and their material.

Beams are traditionally descriptions of building or civil engineering structural elements, but smaller structures such as truck or automobile frames, machine frames, and other mechanical or structural systems contain beam structures that are designed and analyzed in a similar fashion.

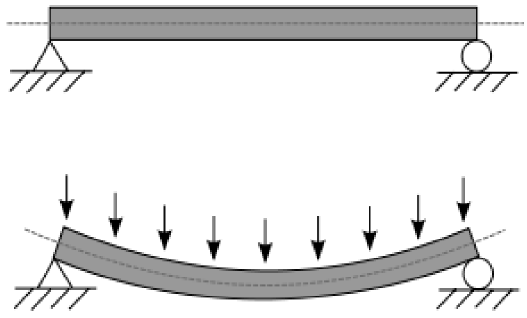

Figure 1: A statically determinate beam, bending (sagging) under a uniformly distributed load

1.1.1 OVERVIEW

Historically beams were squared timbers but are also metal, stone, or combinations of wood and metal such as a flitch beam. Beams generally carry vertical gravitational forces but can also be used to carry horizontal loads (e.g., loads due to an earthquake or wind or in tension to resist rafter thrust as a tie beam or (usually) compression as a collar beam). The loads carried by a beam are transferred to columns, walls, or girders, which then transfer the force to adjacent structural compression members. In light frame construction joists may rest on beams.

In carpentry a beam is called a plate as in a sill plate or wall plate, beam as in a summer beam or dragon beam.

1.1.2 CLASSIFICATION OF BEAMS BASED ON SUPPORTS

In engineering, beams are of several types:

1.Simply supported - a beam supported on the ends which are free to rotate and have no moment resistance.

2.Fixed - a beam supported on both ends and restrained from rotation.

3.Over hanging - a simple beam extending beyond its support on one end.

4.Double overhanging - a simple beam with both ends extending beyond its supports on both ends.

5.Continuous - a beam extending over more than two supports.

6.Cantilever - a projecting beam fixed only at one end.

7.Trussed - a beam strengthened by adding a cable or rod to form a truss.

1.2 CANTILEVER BEAM

A cantilever is a rigid structural element, such as a beam or a plate, anchored at only one end to a (usually vertical) support from which it is protruding. Cantilevers can also be constructed with trusses or slabs. When subjected to a structural load, the cantilever carries the load to the support where it is forced against by a moment and shear stress.

Cantilever construction allows for overhanging structures without external bracing, in contrast to constructions supported at both ends with loads applied between the supports, such as a simply supported beam found in a post and lintel system

1.2.1 APPLICATIONS OF CANTILEVER BEAM

In bridges, towers, and buildings

Cantilevers are widely found in construction, notably in cantilever bridges and balconies (see corbel). In cantilever bridges the cantilevers are usually built as pairs, with each cantilever used to support one end of a central section. The Forth Bridge in Scotland is an example of a cantilever truss bridge. A cantilever in a traditionally timber framed building is called a jetty or forebay. In the southern United States a historic barn type is the cantilever barn of log construction.

Temporary cantilevers are often used in construction. The partially constructed structure creates a cantilever, but the completed structure does not act as a cantilever. This is very helpful when temporary supports, or falsework, cannot be used to support the structure while it is being built (e.g., over a busy roadway or river, or in a deep valley). So some truss arch bridges (see Navajo Bridge) are built from each side as cantilevers until the spans reach each other and are then jacked apart to stress them in compression before final joining. Nearly all cable-stayed bridges are built using cantilevers as this is one of their chief advantages. Many box girder bridges are built segmentally, or in short pieces. This type of construction lends itself well to balanced cantilever construction where the bridge is built in both directions from a single support.

These structures are highly based on torque and rotational equilibrium.

In an architectural application, Frank Lloyd Wright's Fallingwater used cantilevers to project large balconies. The East Stand at Elland Road Stadium in Leeds was, when completed, the largest cantilever stand in the worldholding 17,000 spectators. The roof built over the stands at Old Trafford Football Ground uses a cantilever so that no supports will block views of the field. The old, now demolished Miami Stadium had a similar roof over the spectator area. The largest cantilever in Europe is located at St James' Park in Newcastle-Upon-Tyne, the home stadium of Newcastle United F.C.

Less obvious examples of cantilevers are free-standing (vertical) radio towers without guy-wires, and chimneys, which resist being blown over by the wind through cantilever action at their base.

1.3 AIRCRAFT WING

1.3.1 INTRODUCTION

A fixed-wing aircraft is an aircraft, such as an aeroplane, which is capable of flight using wings that generate lift caused by the vehicle's forward airspeed and the shape of the wings. Fixed-wing aircraft are distinct from rotary-wing aircraft, in which the wings form a rotor mounted on a spinning shaft, in which the wings flap in similar manner to a bird. [1]

Glider fixed-wing aircraft, including free-flying gliders of various kinds and tethered kites, can use moving air to gain height. Powered fixed-wing aircraft that gain forward thrust from an engine (aero planes) include powered paragliders, powered hang gliders and some ground effect vehicles.

The wings of a fixed-wing aircraft are not necessarily rigid; kites, hang-gliders, variable-sweep wing aircraft and aero planes using wing-warping are all fixed-wing aircraft. Most fixed-wing aircraft are flown by a pilot on board the aircraft, but some are designed to be remotely or computer-controlled.

1.4 DELAMINATION

Delamination is a mode of failure for composite materials and metals. Modes of failure are also known as 'failure mechanisms'. In laminated materials, repeated cyclic stresses, impact, and so on can cause layers to separate, forming a mica-like structure of separate layers, with significant loss of mechanical toughness. Delamination also occurs in reinforced concrete structures subject to reinforcement corrosion, in which case the oxidized metal of the reinforcement is greater in volume than the original metal. The oxidized metal therefore requires greater space than the original reinforcing bars, which causes a wedge-like stress on the concrete. This force eventually overcomes the relatively weak tensile strength of concrete, resulting in a separation (or delamination) of the concrete above and below the reinforcing bars.

2. LITERATURE SURVEY

Structural and vibration analysis of delaminated composite beams [2-4]

Delamination is a mode of failure for composite materials. Modes of failure are also known as 'failure mechanisms'. In laminated materials, repeated cyclic stresses, impact, and so on can cause layers to separate, forming a mica-like structure of separate layers, with significant loss of mechanical toughness.

Some manufacturers of carbon composite bike frames suggest to dispose of the expensive frame after a particularly bad crash, because the impact could develop defects inside the material. Due to increasing use of composite materials in aviation, delamination is increasingly an air safety concern, especially in the tail sections of the airplanes. In this thesis, the effects of delamination length on the stresses and natural frequency of symmetric composite beams are analyzed using Ansys software. The composite material considered is carbon fiber. Structural and Frequency analysis are done on the composite beam by varying the delamination lengths.

On the Finite Element Free Vibration Analysis of Delaminated Layered Beams: A New Assembly Technique [2].

The dynamic analysis of flexible delaminated layered beams is revisited. Exploiting Boolean vectors, a novel assembly scheme is developed which can be used to enforce the continuity requirements at the edges of delamination region, leading to a delamination stiffness term. The proposed assembly technique can be used to form various beam configurations with through width delaminations, irrespective of the formulation used to model each beam segment.

The proposed assembly system and the Galerkin Finite Element Method (FEM) formulation are subsequently used to investigate the natural frequencies and modes of 2- and 3-layer beam configurations. Using the Euler-Bernoulli bending beam theory and free mode delamination, the governing differential equations are exploited and two beam finite elements are developed. The free bending vibration of three illustrative example problems, characterized by delamination zones of variable length, is investigated [5-12]. The intact and defective beam natural frequencies and modes obtained from the proposed assembly/FEM beam formulations are presented along with the analytical results and those available in the literature

3. INTRODUCTION TO CAD

Computer-aided layout (CAD) is the usage of computer structures (or workstations) to beneficial useful resource within the introduction, amendment, assessment, or optimization of a design. CAD software is used to boom the productivity of the fashion designer, enhance the superb of layout, beautify communications through documentation, and to create a database for production. CAD output is often inside the shape of digital files for print, machining, or different production operations. The term CADD (for Computer Aided Design and Drafting) is also used.

3.1 INTRODUCTION TO CREO

PTC CREO, previously referred to as Pro/ENGINEER, is three-d modeling software program applied in mechanical engineering, layout, manufacturing, and in CAD drafting provider corporations. It modified into one of the first 3D CAD modeling packages that used a rule-based parametric device. Using parameters, dimensions and functions to seize the behavior of the product, it is able to optimize the improvement product further to the format itself.

The name comes to be changed in 2010 from Pro/ENGINEER Wildfire to CREO. It changed into introduced by means of way of the business enterprise who superior it, Parametric Technology Company (PTC), for the duration of the release of its suite of format merchandise that consists of programs collectively with meeting modeling, 2D orthographic views for technical drawing, finite element analysis and greater

3.1.1 ADVANTAGES OF CREO PARAMETRIC SOFTWARE

1. Optimized for version-primarily based absolutely agencies
2. Increased engineer productivity
3. Better enabled concept format
4. Increased engineering competencies
5. Increased production abilities
6. Better simulation
7. Design talents for additive production

3.1.2 CREO PARAMETRIC MODULES

- Sketcher
- Part modeling
- Assembly
- Drafting
- Sheet metal

3.2 PROBLEM DESCRIPTION

Boundary conditions are given in Table 1.

Table 1: Boundary conditions in design

MATERIALS	CONDITIONS
• Aluminum alloy • Carbon fiber • S2 glass • Kevlar	Simple beam
	Delaminating ratio 0.3
	Delaminating ratio 0.5
	Delaminating ratio 0.0.7

The dimension of cantilever beam and forces acting on cantilever beam can be taken from reference [11].

3.3 MODELS

CONDITION 1: WITHOUT DELAMINATION

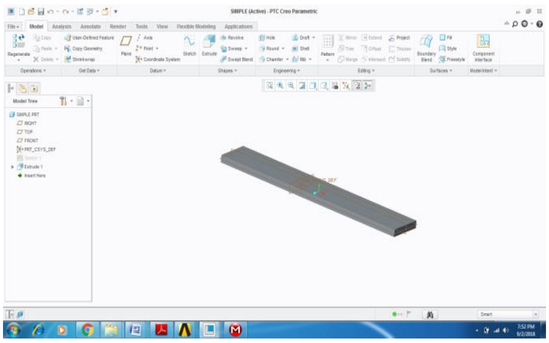

Figure 2: 3D model of simple cantilever beam

CONDITION 2: DELAMINATING LENGTH RATIO 0.3

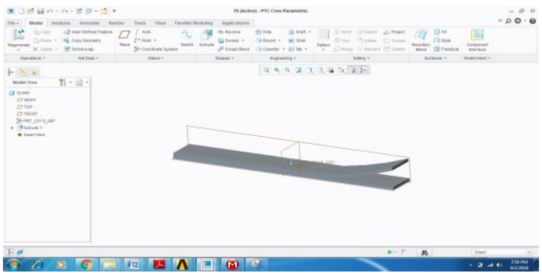

Figure 3: 3D model of delaminated cantilever beam at X-0.3

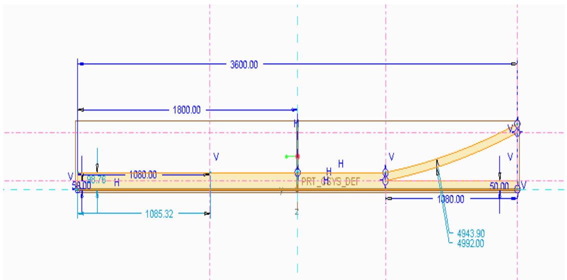

Figure 4: 2D model of delaminated cantilever beam at X-0.3

CONDITION 3: DELAMINATING LENGTH RATIO 0.5

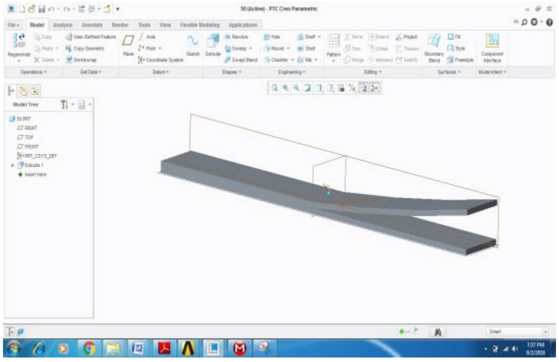

Figure 5: 3D model of delaminated cantilever beam at X-0.5

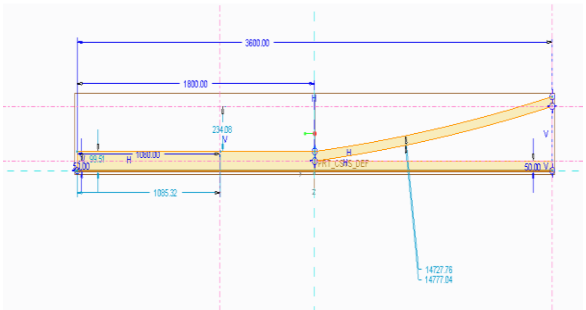

Figure 6: 2D model of delaminated cantilever beam at X-0.5

CONDITION 4: DELAMINATING LENGTH RATIO 0.7

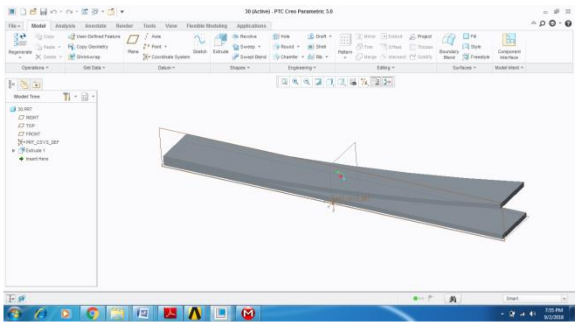

Figure 7: 3D model of delaminated cantilever beam at X-0.7

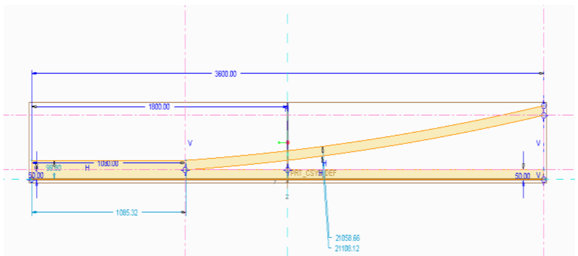

Figure 8: 3D model of delaminated cantilever beam at X-0.7

4. INTRODUCTION TO FEA

Finite detail evaluation is a way of solving, commonly approximately, remarkable problems in engineering and technological understanding. It is used in particular for troubles for which no particular solution, expressible in some mathematical shape, is available. As such, it's miles a numerical instead of an analytical approach. Methods of this type are desired due to the truth analytical techniques cannot cope with the real, complex issues which are met with in engineering.

4.1 STATIC, FATIGUE AND MODAL ANALYSIS OF DELAMINATED BEAMS

4.1.1 USED MATERIALS

- Aluminum alloy
- Carbon fiber
- S2 glass
- Kevlar

4.1.2 MATERIAL PROPERTIES

The material properties of composite materials like Carbon fiber reinforced polymer, S-2 Glass fiber reinforced polymer and Kevlar fiber reinforced are given in Table 2 and Table 3[13-17].

Table 2: Material properties of S-2 Glass fiber reinforced composite material

Property	ASTM Standard	75°F	22°C
Elastic Constants		Msi	GPa
Longitudinal Modulus, E_L	D3039	7.7 - 8.5	53 - 59
Transverse Modulus, E_T	D3039	2.3 - 2.9	16 - 20
Axial Shear Modulus, G_{LT}	D3518	0.9 - 1.3	6 - 9
Poisson's Ratio, u_{LT}	D3039	0.26 - 0.28	0.26 - 0.28
Strength Properties		ksi	MPa
Longitudinal Tension, F^{tu}_L	D3039	230 - 290	1590 - 2000
Longitudinal Compression, F^{cu}_L	D3410	100 - 180	690 - 1240
Transverse Tension, F^{tu}_T	D3039	6 - 12	41 - 82
Transverse Compression, F^{cu}_T	D3410	16 - 29	110 - 200
In-Plane Shear, F^{su}_{LT}	D3518	9 - 24	62 - 165
Interlaminar Shear, F^{isu}	D2344	8 - 15	55 - 103
Longitudinal Flexural	D790	180 - 250	1240 - 1720
Longitudinal Bearing	D953	68 - 80	469 - 552
Ultimate Strains			
Longitudinal Tension, ϵ^{tu}_L	D3039	2.7 - 3.5%	
Longitudinal Compression, ϵ^{cu}_L	D3410	1.1 - 1.8%	
Transverse Tension, ϵ^{tu}_T	D3039	0.25 - 0.50%	
Transverse Compression, ϵ^{cu}_T	D3410	1.1 - 2.0%	
In-Plane Shear, γ^{su}_{LT}	D3518	1.6 - 2.5%	
Physical Properties			
Fiber Volume (%)	D2734	57 - 63%	57-63%
Density	D792	lb/in³ 0.071 - 0.073	g/cm³ 1.96 - 2.02

Table 3: Material properties of Carbon fiber reinforced polymer composite material and Kevlar fiber reinforced composite polymer materials

	Symbol	Units	Std CF Fabric	HMCF Fabric	E glass Fabric	Kevlar Fabric	Std CF UD	HMCF UD	M55** UD	E glass UD	Kevlar UD	Boron UD
Young's Modulus 0°	E1	GPa	70	85	25	30	135	175	300	40	75	200
Young's Modulus 90°	E2	GPa	70	85	25	30	10	8	12	8	6	15
In-plane Shear Modulus	G12	GPa	5	5	4	5	5	5	5	4	2	5
Major Poisson's Ratio	v12		0.10	0.10	0.20	0.20	0.30	0.30	0.30	0.25	0.34	0.23
Ult. Tensile Strength 0°	Xt	MPa	600	350	440	480	1500	1000	1600	1000	1300	1400
Ult. Comp. Strength 0°	Xc	MPa	570	150	425	190	1200	850	1300	600	280	2800
Ult. Tensile Strength 90°	Yt	MPa	600	350	440	480	50	40	50	30	30	90
Ult. Comp. Strength 90°	Yc	MPa	570	150	425	190	250	200	250	110	140	280
Ult. In-plane Shear Stren.	S	MPa	90	35	40	50	70	60	75	40	60	140
Ult. Tensile Strain 0°	ext	%	0.85	0.40	1.75	1.60	1.05	0.55		2.50	1.70	0.70
Ult. Comp. Strain 0°	exc	%	0.80	0.15	1.70	0.60	0.85	0.45		1.50	0.35	1.40
Ult. Tensile Strain 90°	eyt	%	0.85	0.40	1.75	1.60	0.50	0.50		0.35	0.50	0.60
Ult. Comp. Strain 90°	eyc	%	0.80	0.15	1.70	0.60	2.50	2.50		1.35	2.30	1.85
Ult. In-plane shear strain	es	%	1.80	0.70	1.00	1.00	1.40	1.20		1.00	3.00	2.80
Thermal Exp. Co-ef. 0°	Alpha1	Strain/K	2.10	1.10	11.60	7.40	-0.30	-0.30	-0.30	6.00	4.00	18.00
Thermal Exp. Co-ef. 90°	Alpha2	Strain/K	2.10	1.10	11.60	7.40	28.00	25.00	28.00	35.00	40.00	40.00
Moisture Exp. Co-ef 0°	Beta1	Strain/K	0.03	0.03	0.07	0.07	0.01	0.01		0.01	0.04	0.01
Moisture Exp. Co-ef 90°	Beta2	Strain/K	0.03	0.03	0.07	0.07	0.30	0.30		0.30	0.30	0.30
Density		g/cc	1.60	1.60	1.90	1.40	1.60	1.60	1.63	1.90	1.40	2.00

4.2 ANALYSIS IN ANSYS 14.5

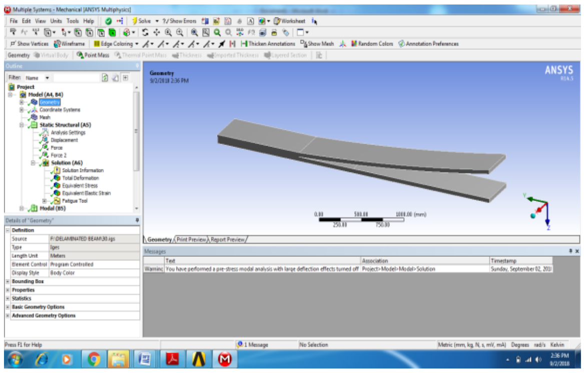

Figure 9: Imported model

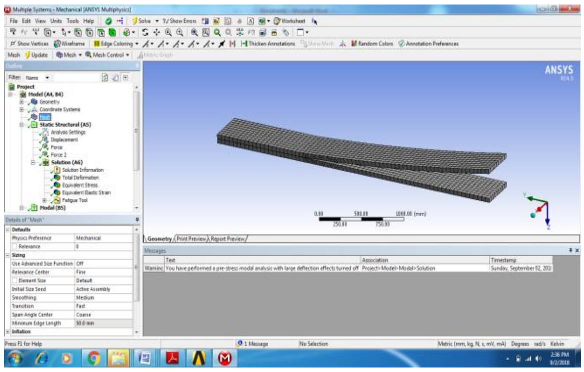

Figure 10: Meshed model

Finite element analysis or FEA representing a real project as a "mesh" a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

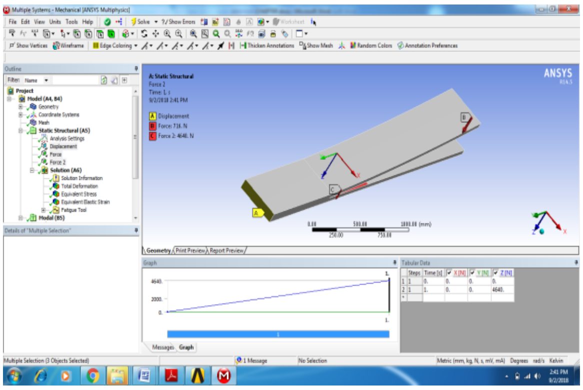

Figure 12: Boundary Conditions

5. ANALYTICAL RESULTS

5.1 MATERIAL- S2 GLASS FIBER REINFORCED POLYMER COMPOSITE

5.1.1 DELAMINATING LENGTH RATIO 0.7

5.1.1.1 STATIC ANALYSIS RESULTS

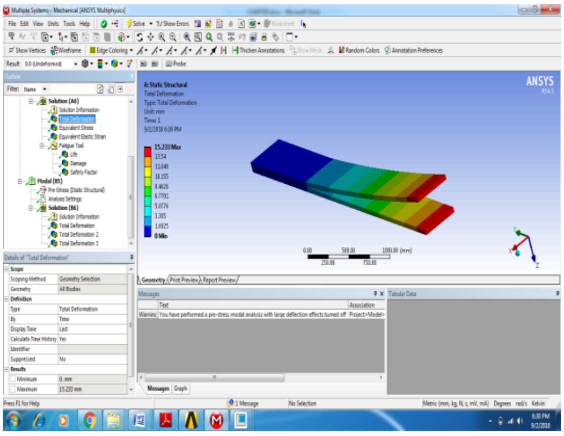

Figure 11: Total deformation of S-2 Glass fiber reinforced polymer composite at X-0.7

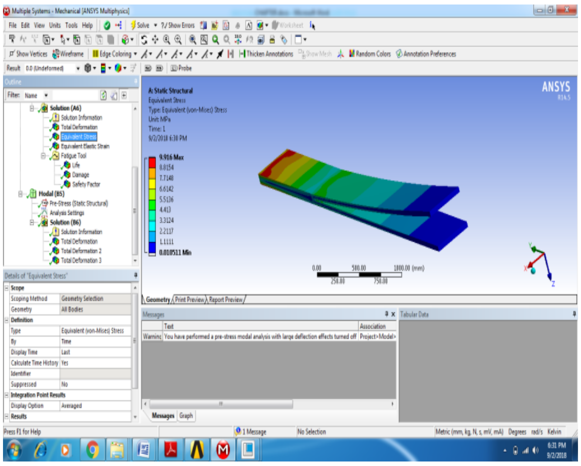

Figure 12: Stress of S-2 Glass fiber reinforced polymer composite at X-0.7

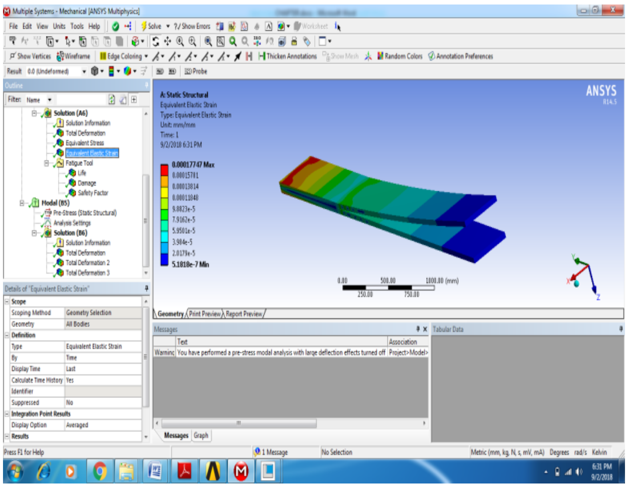

Figure 13: Strain of S-2 Glass fiber reinforced polymer composite at X-0.7

5.1.1.2 FATIGUE ANALYSIS RESULTS

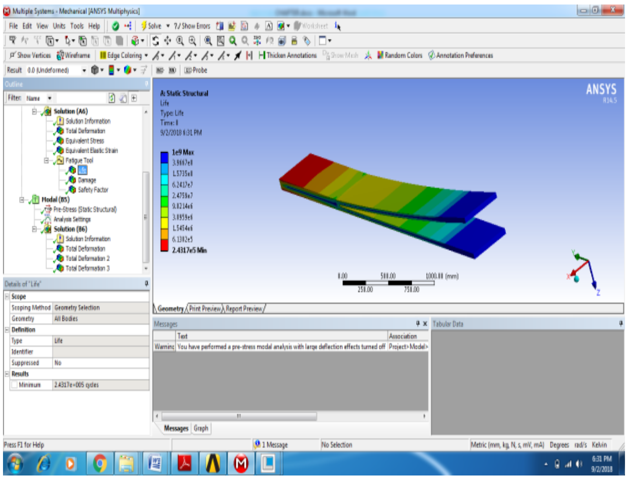

Figure 14: Life of S-2 Glass fiber reinforced polymer composite at X-0.7

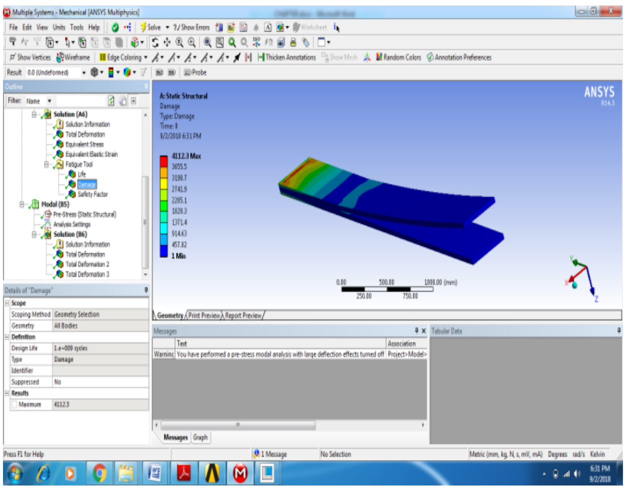

Figure 15: Damageof S-2 Glass fiber reinforced polymer composite at X-0.7

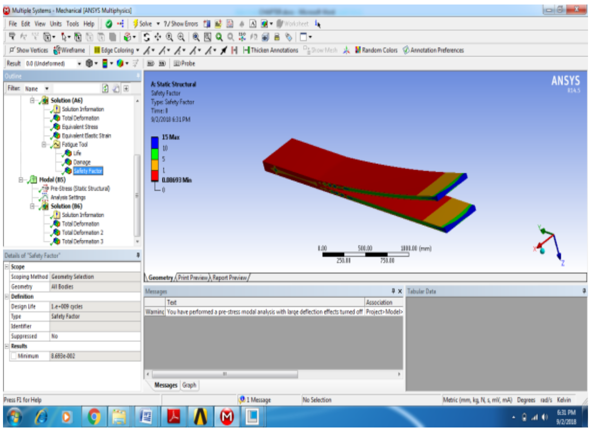

Figure 16: Safety factor of S-2 Glass fiber reinforced polymer composite at X-0.7

5.1.1.3 MODAL ANALYSIS RESULTS

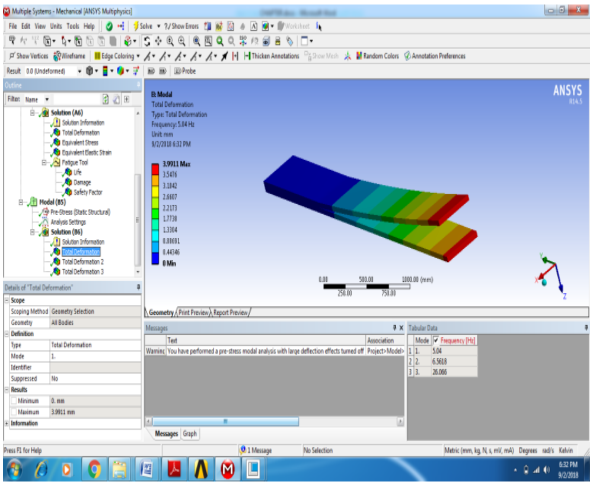

Figure 17: Total deformation 1 of S-2 Glass fiber reinforced polymer composite at X-0.7

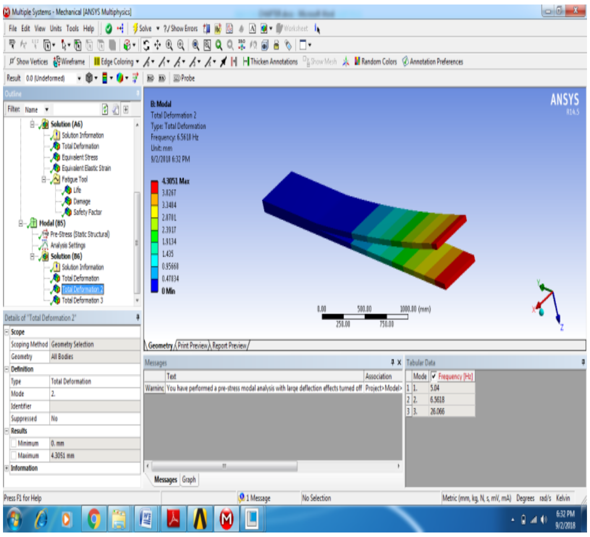

Figure 18: Total deformation 2 of S-2 Glass fiber reinforced polymer composite at X-0.7

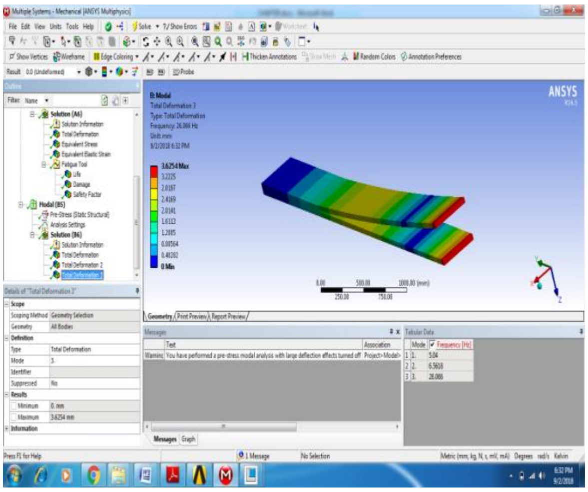

Figure 19: Total deformation 3 of S-2 Glass fiber reinforced polymer composite at X-0.7

5.2 MATERIAL - ALUMINUM ALLAY

5.2.1 DELAMINATING LENGTH RATIO 0.7

5.2.1.1 STATIC ANALYSIS RESULTS

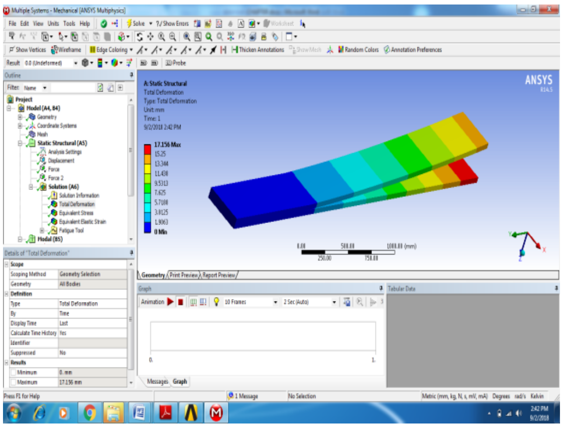

Figure 20: Total deformation of Aluminium alloy at X-0.7

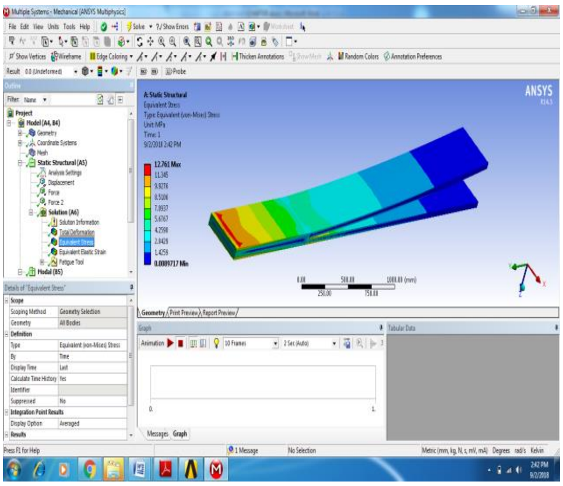

Figure 21: Stress of Aluminium alloy at X-0.7

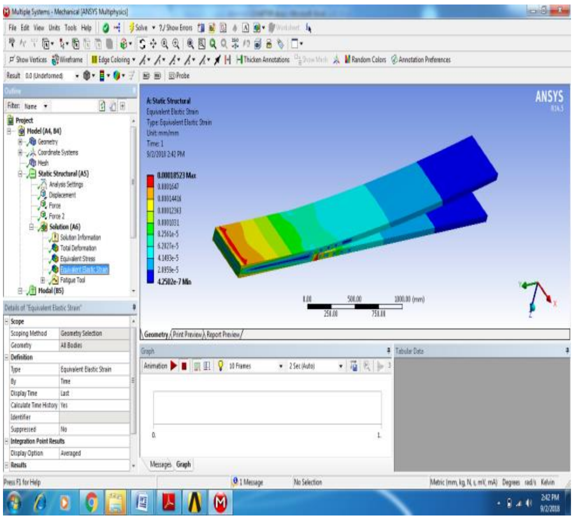

Figure 22: Strain of Aluminium alloy at X-0.7

5.2.1.2 FATIGUE ANALYSIS RESULTS

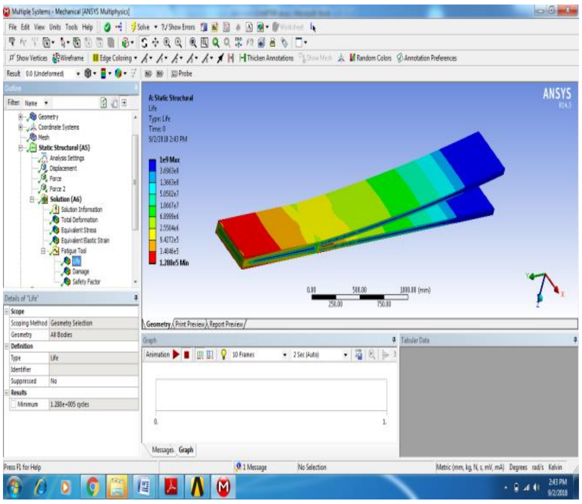

Figure 23: Life of Aluminium alloy at X-0.7

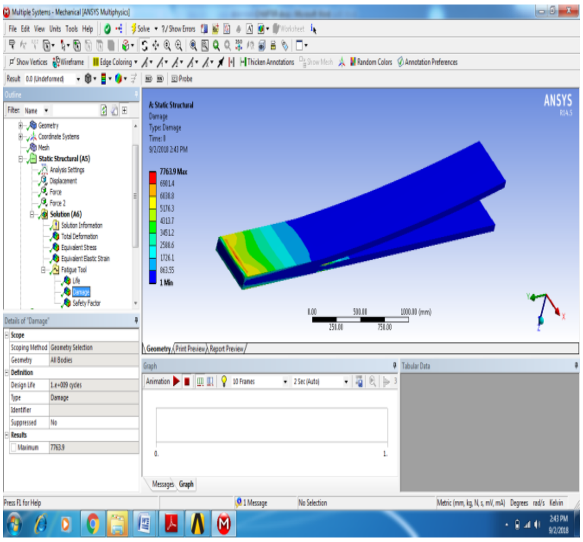

Figure 24: Damage of Aluminium alloy at X-0.7

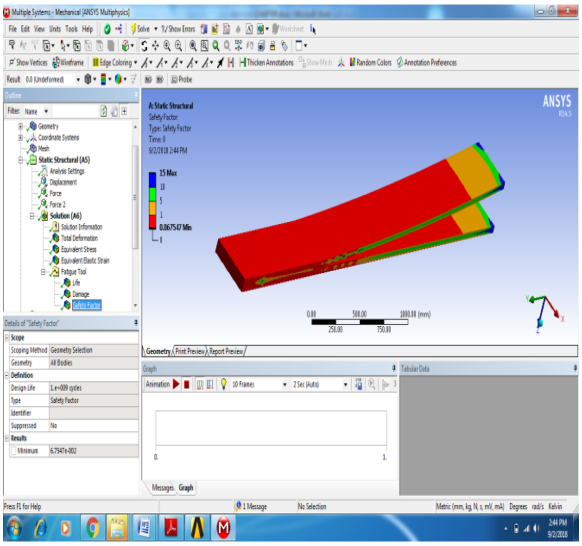

Figure 25: Safety factor of Aluminium alloy at X-0.7

5.2.1.3 MODAL ANALYSIS RESULTS

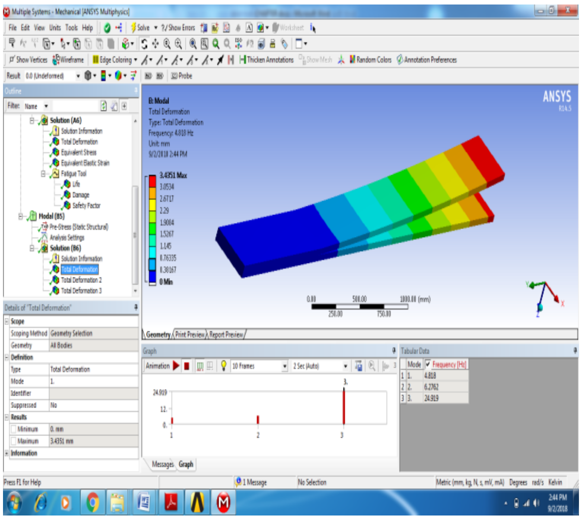

Figure 26: Total deformation 1 of Aluminium alloy at X-0.7

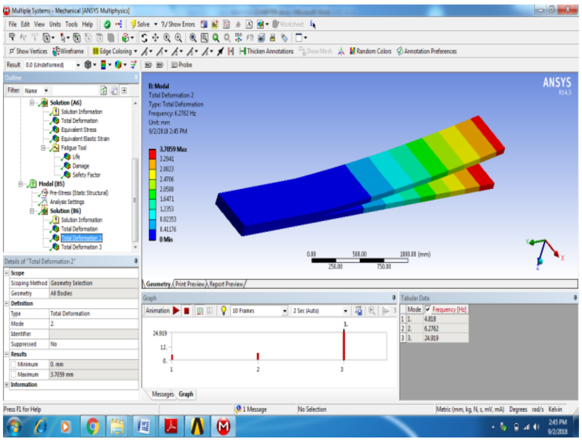

Figure 27: Total deformation 2 of Aluminium alloy at X-0.7

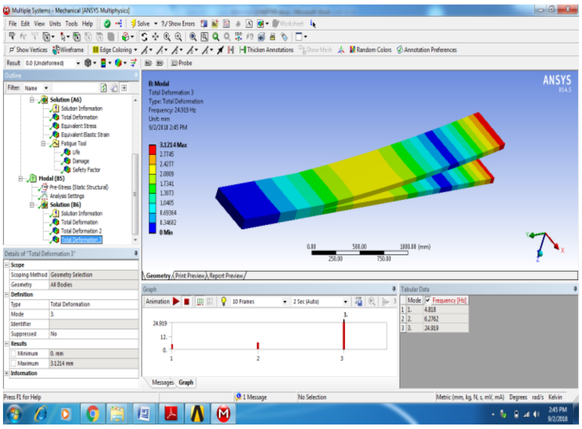

Figure 28: Total deformation 3 of Aluminium alloy at X-0.7

6. RESULTS & DISCURSTIONS

6.1 STATIC STRUCTURAL ANALYSIS RESULTS:

In this study, static structural analysis is done in Ansys 14.5. To obtain the values of Total deformation and equivalent Stress and equivalent Strain of various materials of cantilever beam with rectangular cross section are analyzed with respect to changing the delamination length ratios of beam (X=0, 0.3, 0.5, 0.7) . The results can be tabulated in Table 4.

Table 4: Static structural analysis results of different materials at various delamination positions.

Material	Delamination length ratios	Deformation (mm)	Stress (MPa)	Strain
Aluminum Alloy	With out	6.6367	10.152	0.000014797
	0.3	54.7790	53.014	0.000771610
	0.5	18.2640	19.075	0.000027763
	0.7	17.1560	12.761	0.000018523
Carbon fibre reinforced epoxy polymer	With out	3.6132	13.051	0.000074895
	0.3	21.5230	52.903	0.000303160
	0.5	7.1903	19.074	0.000109300
	0.7	4.8609	10.039	0.000057528
S-2 Glass fibre reinforced epoxy polymer	With out	11.3230	12.888	0.000230910
	0.3	67.5630	52.347	0.000936830
	0.5	20.4710	17.999	0.000322120
	0.7	15.2330	9.916	0.000177470
Kevlar fibre reinforced epoxy polymer	With out	8.3949	13.333	0.000178790
	0.3	50.1350	54.146	0.000724640
	0.5	16.7060	19.480	0.000260710
	0.7	11.2940	10.248	0.000137160

The static structural analysis results are shown in figure 29 & figure 30.

It is also obtain that the deformation and Stress changes with the change of material of beam and the deformation length ratio on the beam.
By observing the static analysis results the stress values are less for **S2-Glass** fiber reinforced composite material compare with Carbon fiber reinforced composite, Kevlar fiber reinforced composite & Aluminum alloy materials at X-0.7 delaminated position. the stress value is **9.916 MPa.**

6.2 FATIGUE ANALYSIS RESULTS:

In this study, fatigue analysis is done in Ansys 14.5. To obtain the values of life, damage and safety factor of various materials like Aluminum alloy, Carbon fiber reinforced composite, S-2 Glass fiber reinforced composite, Kevlar fiber reinforced composite of cantilever beam with rectangular cross section are analyzed with respect to changing the delamination length ratios of beam (X=0, 0.3, 0.5, 0.7) . The results can be tabulated in Table 5.

Table 5: Fatigue analysis results of different materials at various delamination positions

Material	Delamination length ratios	Life	Damage	Factor of safety	
				Min	Max
Aluminum Alloy	With out	1.00E+09	4371.70	0.08491	15
	0.3	1.00E+09	1.00E+32	0.01626	15
	0.5	1.00E+09	20279.00	0.04519	15

	0.7	1.00E+09	7763.90	0.06755	15
Carbon fibre reinforced epoxy polymer	With out	1.00E+09	8209.20	0.06605	15
	0.3	1.00E+09	1.00E+32	0.01629	15
	0.5	1.00E+09	20276	0.04519	15
	0.7	1.00E+09	4246.00	0.08587	15
S-2 Glass fibre reinforced epoxy polymer	With out	1.00E+09	7957.1	0.06688	15
	0.3	1.00E+09	1.00E+32	0.01647	15
	0.5	1.00E+09	17692	0.04787	15
	0.7	1.00E+09	4112.3	0.08693	15
Kevlar fibre reinforced epoxy polymer	With out	1.00E+09	8657.2	0.06465	15
	0.3	1.00E+09	1.00E+32	0.01592	15
	0.5	1.00E+09	21281	0.04425	15
	0.7	1.00E+09	4480	0.08411	15

By observing the static structural analysis results shown in figure 31, it is obtained that the damage and safety factor changes with the change of material of beam and the deformation length ratio on the beam.

By observing the fatigue analysis results, safety factor more for s2 glass fiber reinforced composite material at X-0.7 delaminated position. safety factor value is **0.08693.**

6.3 MODAL ANALYSIS RESULTS:

In this study, modal analysis is done in Ansys 14.5.

Table 6: Modal analysis results of different materials at various delamination positions

Material	Delamination length ratios	Mode 1 frequency	Mode 2 frequency	Mode 3 frequency
Aluminum Alloy	With out	9.0404	40.2250	56.3590
	0.3	6.1683	27.7470	31.2920
	0.5	5.8222	12.1320	26.1100
	0.7	4.8180	6.2762	24.9190
Carbon fibre reinforced epoxy polymer	With out	18.7180	83.2780	116.6800
	0.3	12.7710	57.4490	64.7870
	0.5	12.0540	25.1190	54.0550
	0.7	9.9756	12.9950	51.5900
S-2Glass fibre reinforced epoxy polymer	With out	9.4552	42.1210	58.9530
	0.3	6.4524	29.0590	32.6770
	0.5	6.0902	12.6760	27.3070
	0.7	5.0400	6.5618	26.0660
Kevlar fibre reinforced epoxy polymer	With out	13.1290	58.3160	81.8340
	0.3	8.9556	40.2180	45.5530
	0.5	8.4539	17.6470	37.9210
	0.7	6.9956	9.1202	36.1820

To obtain the values of life, damage and safety factor of various materials like Aluminum alloy, Carbon fiber reinforced composite, S-2 Glass fiber reinforced composite, Kevlar fiber reinforced composite of cantilever beam with rectangular cross section are analyzed with respect to changing the delamination length ratios of beam (X=0, 0.3, 0.5, 0.7) .The results can be tabulated in Table 6.

Modal analysis is done to determine the natural frequencies. By observing the analysis results in figures32 to 34.

The natural frequencies decreased with an increase in delamination length ratio on the beam.

It is also obtain that the natural frequencies changes with the change of material of beam and the deformation length ratio on the beam.

By observing the modal analysis results the frequency values are less for Aluminum alloy, S-2 Glass material. so that the less vibrations are formed in Aluminum alloy, S-2 Glass material

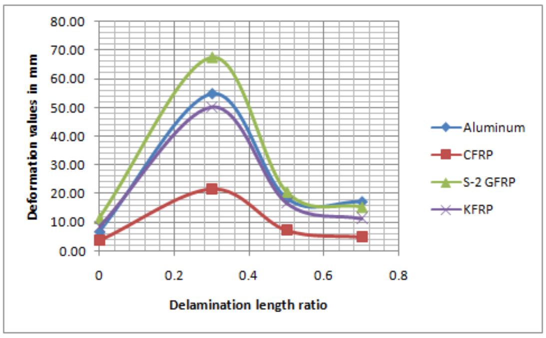

Figure 29: deformation values of different materials v/s delamination ratios

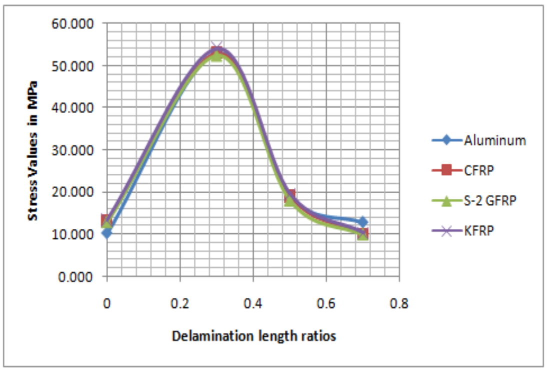

Figure 30: Stress values of different materials v/s delamination ratios

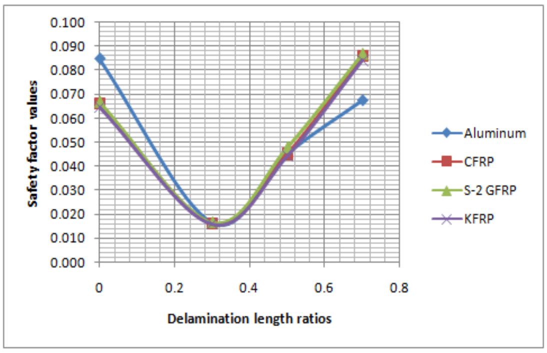

Figure 31: Safety factor of different materials v/s delamination ratios

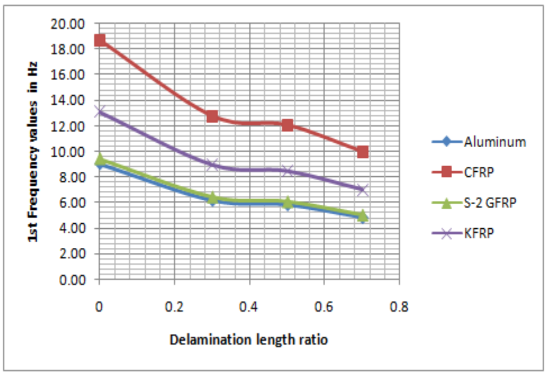

Figure 32: 1st frequency of different materials v/s delamination ratios

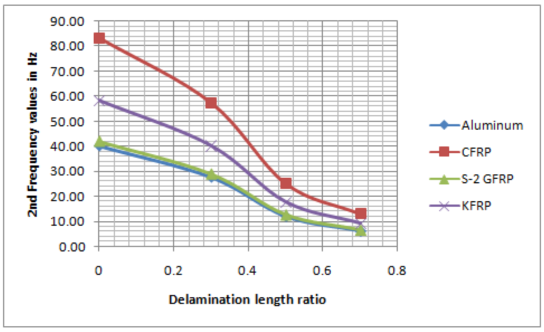

Figure 33: 2nd frequency of different materials v/s delamination ratios

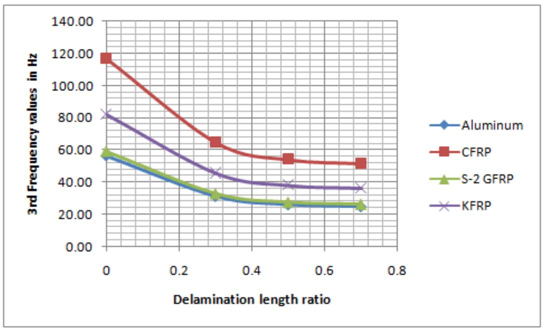

Figure 34: 3rd frequency of different materials v/s delamination ratios

7. CONCLUSION

In this paper the aircraft wing beam with different delimitation positions (X-0, X-0.3, X-0.5 & X-0.7) designed in CREO parametric software and analyzed in ANSYS software to analyze the strength, safety factor and natural frequency of different materials at different delamination positions. Static structural, Fatigue and Modal analysis are performed done on the rectangular cantilever composite beam with single-edge delamination. Static analysis is used to determine the deformation, stress and strain of different materials of beam at different delaminated positions. Modal analysis is used to determine the deformations with respect to frequencies, fatigue analysis to estimate the life of the beam, safety factor of beam.

- By observing the static analysis results, the stress values are less for **S2-Glass**fiber material compare with Carbon fiber, Kevlar fiber & Aluminum alloy materials at X-0.7 delaminated position and the stress value is **9.916 MPa.**
- By observing the modal analysis results, the frequency values are less for Aluminum alloy, S-2 Glass fiber material, so that less vibrations are formed in Aluminum alloy, S-2 Glass material.
- By observing the fatigue analysis results, safety factor is more for S-2 glass fiber material at X-0.7 delaminated position. And the safety factor value is **0.08693.**

So it can be concluded that beam at X-0.7 delaminated position, S-2 Glass fiber reinforced composite material has given better performance than Conventional material (Aluminium alloy). Therefore Aluminium alloy material can be replaced with S-2 Glass fiber reinforced composite material.

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